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RESEARCH DEPARTMENT

Television co-channel interference: PAL transmissions

RESEARCH REPORT No. RA-13

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TELEVISION CO-CHANNEL INTERFERENCE: PAL TRANSMISSIONS

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for Head of Research Department

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SUMMARY

Subjective tests of the impairment produced by co-channel interference are described, with particular reference to PAL colour transmissions and the use of precision control of the vision carrier frequencies, and suitable protection ratios for planning purposes are recommended.

1. INTRODUCTION

Previous investigations[1-6] have resulted in a fairly detailed knowledge of the effects of co-channel interference with monochrome transmissions, but less information is available concerning the effects of colour. Such work that has been reported has been primarily concerned with the NTSC system[7,8], although some results have been obtained for the PAL system[9].

This report is concerned with the effects of co-channel interference with PAL colour transmissions (on the 625-line standard), with particular reference to the case in which the vision carriers are in the condition known as 'precision offset' and presents the results of some subjective tests. At the same time, the protection ratios required for monochrome transmissions are re-assessed.

2. EXPERIMENTAL ARRANGEMENT

2.1. Generation of Vision Carrier Frequencies

The subjective tests required the generation of two u.h.f. carriers having a frequency difference (offset) of about 2 Hz or 10·400 kHz, corresponding to nearly zero and two-thirds line-scan frequency offsets, controlled very precisely (± 1 Hz). A block diagram of the arrangement for producing a 10·400 kHz offset is shown in Fig. 1(*a*). The 'wanted' carrier was generated at 57 MHz. The same carrier was used, together with a 10·400 kHz signal, to generate the 'interfering' carrier by a process of quadrature modulation, giving a suppressed-carrier single-sideband signal having a frequency equal to 57 MHz + 10·400 kHz. The original carrier and the derived carrier were then fed to two separate video modulators corresponding to the wanted and interfering transmissions respectively. The modulated

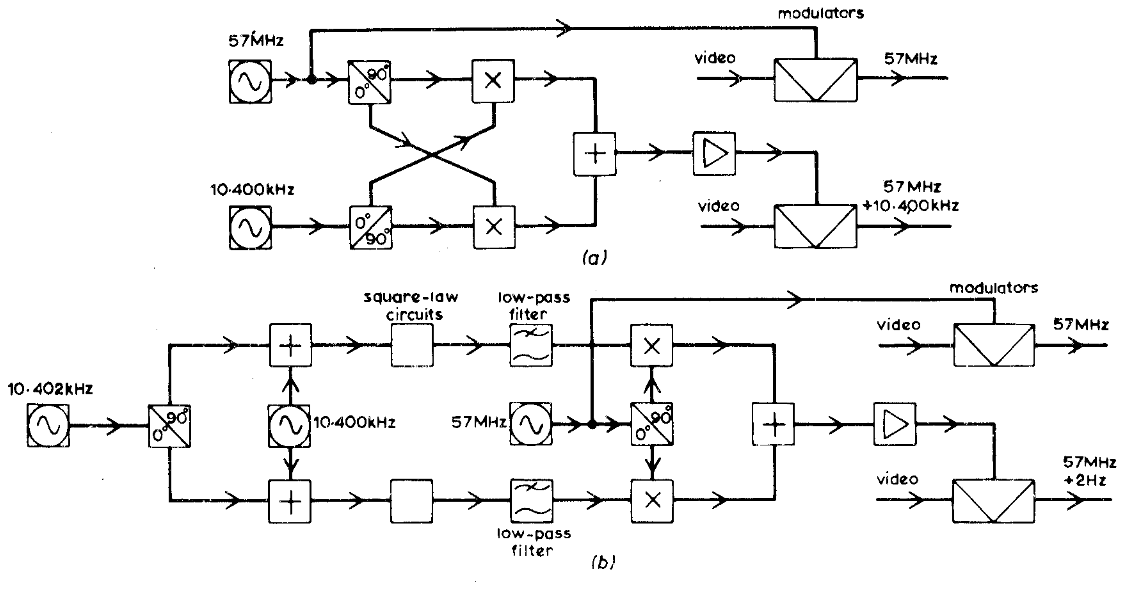


Fig. 1 - Methods of generating 'offset' signals

signals were finally combined via suitable attenuators, and the signal was frequency-converted to a suitable channel in the u.h.f. band.

A similar arrangement, shown in Fig. 1(*b*), was used to generate the 2 Hz offset frequency, but in this case the 2 Hz was produced by beating together two 10·4 kHz oscillators.

2.2. The Video Modulation

The 'wanted' picture, a 'still', was obtained from a slide scanner and, for most of the tests in which colour effects were being investigated, the picture was chosen to provide a good variety of well-saturated colours covering reasonably large areas of the television screen. The carrier was fully modulated by the video signal in accordance with the specification for U.K. Standard I. A variety of signals was used to modulate the interfering carrier. Because a second PAL-coded signal was not available, a simulated colour signal was employed for some of the tests. The modulation for the interfering signal, during the active picture period, was then obtained from a c.w. source at the sub-carrier frequency, with no phase switching from line to line, the peak-to-peak excursion being from 5% to 95% of the normal black-to-white excursion. Checks carried out later, when a second PAL signal became available, showed that the impairment produced by the continuous sub-carrier was at least as great as that produced by a picture, and the subjective results obtained can therefore be considered as conservative. The phase or timing of the synchronizing pulses of the interfering signal, relative to those of the wanted signal, was controllable, and for most of the tests was adjusted so that the line and field pulses of the interfering signal occurred during the picture period of the wanted signal.

2.3. The Receivers

The monochrome display was normally produced on a 21 inch monitor, fed by a high-grade laboratory receiver, and synchronized by pulses from the video sync.-pulse generator. Comparative checks were made from time to time on a number of domestic receivers, and such a receiver was used for the tests in which effects of the interference on time-base synchronizing were investigated.

The colour receiver for most of the tests was a 21 inch (circular tube) delay-line type which could be used as a video monitor, but using its own synchronizing circuits for the time bases. It was fed with video signals from the laboratory receiver, which was operated at a fixed gain. For a few of the tests this receiver was not available, and a 25 inch (rectangular tube) domestic delay-line receiver was used.

It may thus be seen that suitable account was taken throughout the tests of the effect of the interference upon the synchronization of the receiving equipment.

3. THE SUBJECTIVE TESTS

The observers taking part in the tests were technical or secretarial staff, whose work did not normally involve making close examination of television pictures. Such observers may probably be regarded as a sample of reasonably critical viewers. The number of observers for each test varied from seven to sixteen. In order to avoid unintentional mutual influence the observers made their assessments singly. Various levels of the interference (including in most tests a 'control' case in which there was no intentional interference) were presented in a random order, and the observer was asked to grade the impairment according to the EBU impairment scale, which is tabulated below:

1. Imperceptible
2. Just perceptible
3. Definitely perceptible, but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

In an experiment with a number of observers it is useful to take the average of the numbers corresponding to the subjective grades, thus producing a mean grade for a particular condition. Thus, fractional grades can be obtained which are not exactly defined by subjective descriptions.

The normal viewing distance was five times the picture height, but the observer was invited to move a little if he found this viewing distance uncomfortable. In one or two cases the observer did move a small distance further away from the screen.

A diffuse low-level general lighting was used, and care was taken to reduce reflexions on the screen as much as possible.

For various reasons it was not practicable to standardize precisely the ambient illumination or the screen brightness but, from the point of view of co-channel interference effects, it is considered that no significant errors were produced by this cause.

4. RESULTS OF TESTS

The results of all the tests are given in Figs. 2 to 19, and will be discussed stage by stage, starting with the simplest type of interference effect which occurs for monochrome transmissions. The parameters relating to each test are given in the table adjoining the figures.

Each figure summarizes the results of a particular test, using curves derived as follows. For each carrier ratio examined, the arithmetic mean grade and the standard deviation of the observations were calculated. The standard error of the mean and a corrected standard deviation were then derived, taking into account the number of observers in the test. Smooth curves were then drawn to indicate the mean, with the appropriate confidence limits; there is a 90% probability that the mean grading assessment by a large number of viewers would lie within the hatched area. The dotted lines are spaced $\pm\sigma$ from the mean, where σ is the smoothed corrected standard deviation. The procedure[1] used implies a Normal distribution of the scores for each assessment; this may not be a strictly correct assumption, but it is adequate for the present purpose.

Although colour transmissions are subject to additional forms of impairment, luminance effects still occur as in monochrome transmissions, and these may be the most important factor in determining protection ratios. In order to form a reference for comparing with other work, and for assessing the significance of specific colour effects, impairment grading scales relating to monochrome transmissions were established, and these are discussed in Section 4.1. Further tests (discussed in the ensuing sections) were carried out to find if greater protection ratios are required as a result of interference between luminance and chrominance signals.

4.1. Unwanted Luminance Interfering with Wanted Luminance

Subjective assessments were made of interference between monochrome transmissions for various offsets, and the results are summarized in Table 1, which quotes the relevant figure numbers.

It is of interest to compare these results with the protection ratios recommended by the CCIR[10], which are given for an impairment that is 'tolerable' if it occurs for only a small percentage of the time (1 to 10%). In the past it has been found that this impairment criterion corresponds roughly with a mean grade of 3·5 on the EBU impairment scale, i.e., the impairment, if continuously maintained, is on the verge of becoming somewhat objectionable. It is therefore convenient to use grade 3·5 as a basis of comparison, and the carrier ratios corresponding to this value, as given by the curves in the figures, are given in Table 1. The relevant CCIR protection ratio is also shown.

TABLE 1

Monochrome Transmissions
Protection Ratio Required for Mean Impairment Grade 3·5

Vision Carrier Offset	Protection Ratio, dB		Fig. No.
	CCIR	Subjective Tests	
(a) 500 Hz	45	49	2
(b) 2 Hz	35 to 40	35·5	3
(c) 10·425 kHz ± 1 Hz	30	32·5, 35	4,5
(d) 10·400 kHz ± 1 Hz	20	16,28	6,7

(a) Nominal zero offset

The 500 Hz offset (Fig. 2) is intended as a typical value within the 0 to 1000 Hz range that may arise with the ± 500 Hz tolerance normally permitted for vision carrier frequencies. The test is somewhat critical, because of the type of modulation (grill pattern) of the interfering signal, and because 500 Hz is an exact harmonic of the field frequency, resulting in maximum visibility. It is therefore not unexpected that the result should be 4 dB higher than the CCIR ratio.

(b) Precision zero offset

The result for the 2 Hz offset is given in Fig. 3, and the ratio for grade 3·5 impairment comes close to the lower CCIR limit. The CCIR figure is in fact quoted for offset frequencies of 'less than 50 Hz' so that an exact comparison is not possible. A similar result was obtained by Hopf[5], for just tolerable impairment.

(c) Nominal two-thirds line-frequency offset

The 10·425 kHz offset is that producing the most visible interference pattern for offsets in the region of two-thirds line-frequency. Figs. 4 and 5 are relevant. In both cases a somewhat higher ratio than the CCIR figure for nominal two-thirds line-frequency offset is indicated, but there is good agreement with Hopf, who also examined the most visible condition. Since the practical situation with 1000 Hz offset tolerance corresponds to variations in time between the most and least visible conditions, the CCIR figure of 30 dB for planning purposes is reasonable.

(d) Precision two-thirds line-frequency offset

The 10·400 kHz offset is the 'precision best' value. The condition for minimum pattern visibility is that the offset should differ from the nearest multiple of the line frequency by an odd multiple of half the field frequency. It is for this offset that effects upon receiver time-base synchronization are likely to be the most troublesome, because of the relatively high level of interfering signal which can be tolerated. The very different values for the ratio given for 10·400 kHz offset result from rather extreme cases. In Fig. 6 the offset was very precisely controlled to obtain a stationary interference pattern, while in Fig. 7 the offset was 1 Hz from the optimum and a stringent condition for the interfering signal was chosen. The large differences between the required protection ratios in the two cases illustrates the fact that great caution must be observed in interpreting the results of a small number of tests.

More information is available from experiments with colour transmissions, as discussed in the following sections, but it is useful at this point to mention the tests with a monochrome receiver on which Fig. 8 is based. The results include the effect of receiver synchronizing; it will be seen that, with the domestic receiver employed, the impairment increases rapidly with interfering signal level, a change of signal ratio from 26 dB to 22 dB giving a change of 2·5 in the impairment grade. The ratio indicated for grade 3·5 is 23·5 dB.

4.2. Unwanted Chrominance Interfering with Wanted Luminance

This case represents the interference produced on a monochrome receiver by the chrominance signal of an interfering colour transmission. At present, few monochrome receivers have notch filters to reject the colour sub-carrier; most have a significant response at this frequency.

In the case of an interfering signal having a nearly zero offset between the vision carriers, the type of interference produced will be similar to that caused by a colour sub-carrier on the wanted transmission, and if the appropriate monochrome protection ratios are applied the interfering pattern will be imperceptible. This has been confirmed by subjective tests (which are not presented in this report). A case which is worth considering, however, is that of a colour receiver receiving a monochrome transmission, with an interfering colour transmission having a nearly zero offset. The presence of the interfering chrominance information may tend to operate the 'colour killer' circuits of the receiver, and produce an objectionable type of spurious colouring of the picture. This effect was observed to occur on one receiver at a relative interfering level of −29 dB.

In the case of an interfering signal having a vision carrier offset of the precision optimum two-thirds line-frequency, the situation is not quite so favourable as far as pattern effects are concerned, because the frequency of the interfering colour sub-carrier is not at the optimum offset with respect to the wanted luminance carrier. The visibility of the pattern due to the interfering chrominance signal will be increased relative to the visibility of the wanted sub-carrier. This occurs, first, because the difference of either the unswitched or the switched sub-carrier frequency from a line-frequency harmonic is only about one twelfth (1 - 2/3 - 1/4) of line frequency, so giving rise to a coarse-structure pattern, and second, because the difference is close to an integral multiple of the field-scan frequency, so that the pattern moves relatively slowly.

In order to assess the importance of this effect, Fig. 6 should be compared with Fig. 9. The wanted signal was a monochrome picture, and the interfering vision carrier was two-thirds line-frequency precision offset, giving minimum visibility of interfering pattern due to the vision carrier. The interfering modulation was colour bars of full amplitude and 95% saturation, of which the chrominance information was switched on in the case of Fig. 9 and off in Fig. 6. It may be seen that for a given grade of impairment the protection ratio has to be about 3 dB greater when the chrominance is switched on than when it is switched off. However, it must be borne in mind that this is for a case in which the vision carrier was very precisely offset, and for which the protection ratio (with no chrominance signal) for grade 3·5 impairment is about 16 dB. Because other limitations demand a protection ratio of at least 20 dB, the effect of this type of chrominance interference in practice is likely to be insignificant.

4.3. Luminance Signal Interfering with Chrominance Signal

The next condition to be discussed is disturbance to reception of a colour transmission by the vision signal (luminance component) of an interfering transmission.

For nearly zero offset the beat frequency between the vision carriers tends to phase-modulate the wanted carrier and hence to phase-modulate the wanted chrominance signal after detection. For non-precision offsets the large protection ratio required for other reasons ensures that this effect is not significant.

For precision zero offsets, smaller protection ratios are permitted, but in this case the beat frequency is much lower (a few hertz), and the colour sub-carrier reference oscillator will follow the frequency changes, so that the effect upon hue can be neglected.

For the case of two-thirds line-frequency precision offset interference, however, the effect is more important, because of the small protection ratio indicated from monochrome experiments. The unswitched wanted colour components will be phase-modulated by the beat frequency to produce hue patterns corresponding to two-thirds line-frequency offset. In addition, the switched colour components will produce coarse hue patterns corresponding to one-sixth (2/3 - 1/2) line-frequency offset. It may be noted that these patterns can only occur in coloured areas of the picture.

For certain pictures these patterns cause an increased impairment on a colour receiver, compared with that on a monochrome receiver displaying the same picture, but the subjective tests have shown (compare, for example, Figs. 10 and 11) that in general the protection ratio required for grade 3·5 impairment is scarcely increased by these effects.

4.4. Chrominance Signal Interfering with Chrominance Signal

Finally we consider the effect of the chrominance component of an interfering signal on receiving a wanted colour transmission. For nearly zero offset between vision carriers, a low-frequency beat occurs between the sub-carriers; the beat frequency is also affected by any small difference between the sub-carrier frequencies. This beat causes periodic changes in hue and saturation, and to some extent, of luminance. Comparing Figs. 12 and 13, which show the subjective impairment when both vision carriers and colour sub-carriers were offset by 2 Hz, the colour receiver tended to require a slightly smaller (1 to 2 dB less) protection ratio than the monochrome receiver. This apparent difference, however, could be explained by slight changes in experimental conditions, and it is not believed to be of practical significance. One effect which has been observed is a greatly increased fluctuation of saturation due to the effect of the interfering colour information occurring during the wanted colour-burst period, affecting the chrominance a.g.c. circuits of the receiver. This can produce a very noticeable impairment. With the receiver employed in the test, it did not occur for interfering levels corresponding to the recommended planning ratio, but only at somewhat higher levels; nevertheless the effect could be troublesome if the chrominance a.g.c. circuits are rather sensitive.

In the case of two-thirds line-frequency offset, the chrominance signal of the interfering transmission will be demodulated, and can produce a horizontal coloured pattern corresponding to the two-thirds line-frequency offset or a coarser one-sixth line-frequency offset pattern, depending upon the relative proportions of the switched and unswitched components; unlike the phenomenon discussed in Section 4.3, this can occur in uncoloured areas of the wanted picture. This effect has been observed on certain pictures, but tests (discussed below) have shown that it does not require a greater protection ratio than that demanded by other factors. Effects on the a.g.c. circuit did not occur with two-thirds line-frequency offset interference, presumably because of the slow response time of the chrominance a.g.c. circuits.

4.5. Review of Subjective Tests Involving Colour Transmissions

Sections 4.2 to 4.4 have discussed the additional impairments that may arise through the presence of a chrominance sub-carrier signal in the wanted and/or interfering signals. It was seen that no increase in protection ratio appeared to be necessary, on the evidence of the tests that were discussed. Further results, including other combinations of picture material and test conditions, are given in Figs. 14 to 19 inclusive.

Figs. 14 and 15 show the results obtained on a monochrome and on a colour receiver, respectively, for a well-saturated colour picture, the vision carriers being offset by 2 Hz, and the interfering modulation being a c.w. sub-carrier. There is no significant difference in the required protection ratios.

In Figs. 16 to 19, the carriers are offset by 10·400 kHz. The results of Fig. 16 apply to a well-saturated colour picture, viewed on a colour receiver, the interfering modulation being the same picture as the wanted one. In Fig. 17 conditions are similar, except that the colours are less saturated. In Fig. 18 the interfering synchronizing pulses occur during the picture period of the wanted signal. Fig. 19 represents the same conditions as Fig. 18, but the picture is viewed on a monochrome receiver.

Information on the ratios corresponding to grade 3·5 impairment from all the tests involving colour transmissions is summarized in Table 2. From this table it is seen, first, that there is no significant difference between the results obtained on the monochrome and the colour displays, i.e., that monochrome and colour receivers will be subject to much the same degree of co-channel interference to a colour transmission in any situation involving precision-offset carriers. Secondly, comparing Table 2 with Table 1, in order to assess the effect of introducing a chrominance sub-carrier, the

TABLE 2

Colour Transmissions with Precision Offsets

Protection Ratio Required for Mean Impairment Grade 3·5

Vision Carrier Offset	Protection Ratio, dB		Fig. No.
	Monochrome Display	Colour Display	
2 Hz	32, 34·5		14,13
2 Hz		31·5, 33·5	15,12
10·400 kHz	19·0 to 24·5		8,9,11,19
10·400 kHz		22 to 25	10,16,17,18

colour transmissions for 2 Hz carrier offset appear to require a slightly lower protection ratio than monochrome transmissions, but this is probably fortuitous, bearing in mind the large spread in the subjective assessments. There appears to be no significant difference in the results for 10·400 kHz carrier offset. These results tend to confirm that no extra protection ratio is required if colour transmissions replace monochrome transmissions.

A comparison of Figs. 13 and 14, and of Figs. 12 and 15, appears to indicate that increasing the colour sub-carrier offset from less than 1 Hz to 2 Hz results in an increase of about 2 dB in the required protection ratio. However, bearing in mind the spread in the results, this may not be significant.

5. LIMITATIONS OF TESTS

While there are inevitable limitations in the conclusions which can be drawn from a restricted number of tests, it is felt that the information obtained, together with results already published elsewhere, is sufficient to enable protection ratios to be recommended for planning purposes. All the results obtained have related to still pictures; movement of the picture can in certain cases increase the impairment and in other cases can reduce it. In particular it might be expected that the improvement which can be obtained by precision two-thirds line-frequency offset could be reduced by vertical picture movement, causing the eye to strobe the nearly horizontal interference pattern. Work that has been carried out elsewhere[4,7] has tended to indicate that a small increase (not more than 2 dB) may be required for moving pictures but these tests applied to line standards other than 625 lines. Further tests are therefore being carried out for precision offsets of this type, using moving pictures. Preliminary results indicate that, for similar classes of observer to those employed in the tests discussed in this report, a protection ratio of about 24 dB (for grade 3·5 impairment) is adequate.

Most of the results obtained have been for cases in which the offset of the vision carriers and of the colour sub-carriers has been within 2 Hz of the nominal value.

6. CONCLUSIONS

Although it is possible to find particular combinations of wanted and interfering pictures for which the impairment is greater for colour than for monochrome transmissions, nevertheless the general conclusion is that, considering the whole range of pictures likely to occur in practice, PAL colour transmissions do not require greater protection ratios than monochrome.

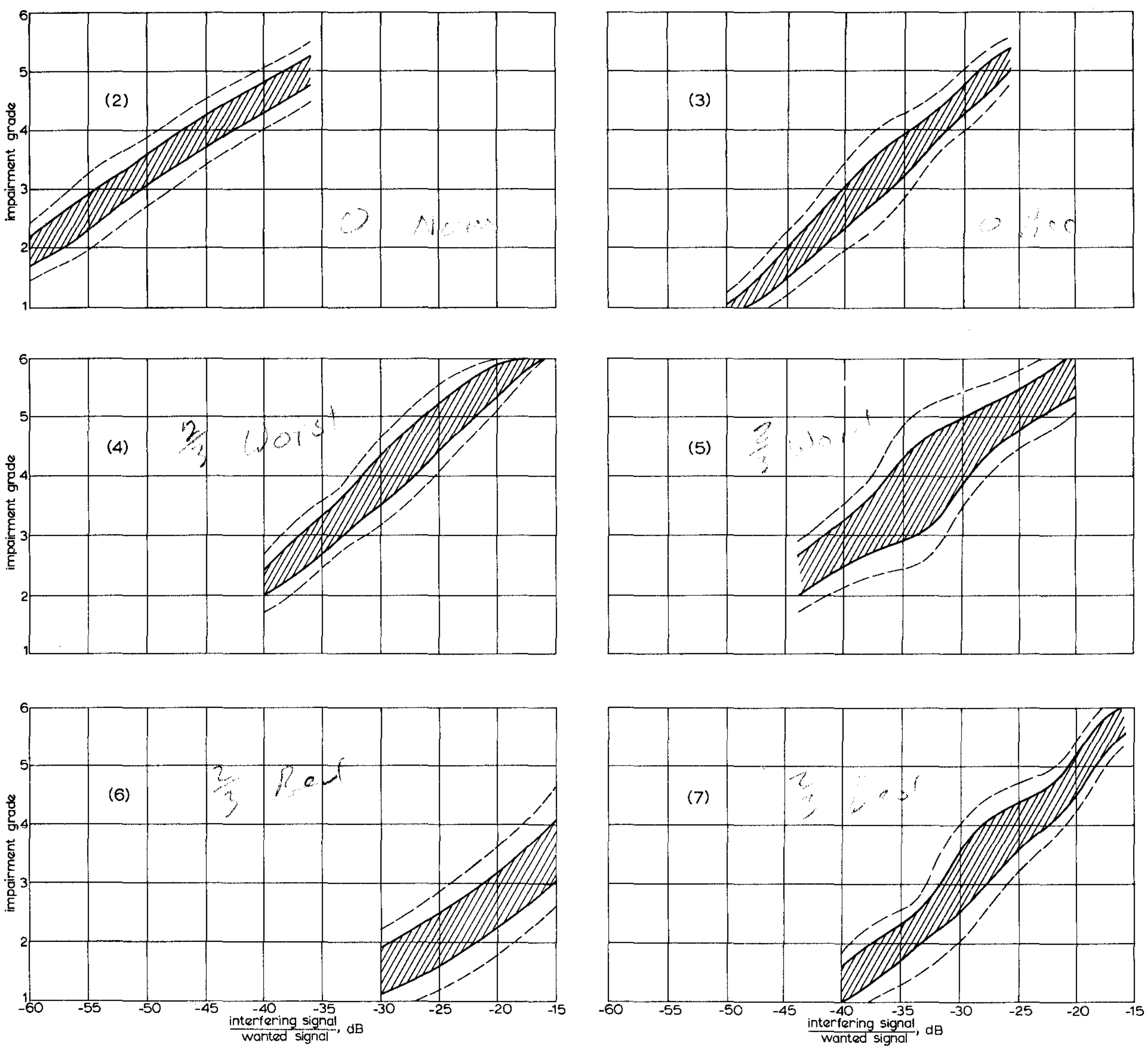
If planning is based upon the protection ratios corresponding to grade 3·5 impairment, the following conclusions can be drawn:-

(i) For non-precision zero offset (with a typical difference of 500 Hz between the vision carrier frequencies) the figure of 45 dB recommended by the CCIR may require to be increased to 49 dB.

(ii) For precision zero offset (carrier frequencies within 2 Hz), a protection ratio of about 33 dB is required. The CCIR recommendation is 35 to 40 dB, but this is intended to apply to frequency offsets of up to 50 Hz.

(iii) For non-precision offsets in the region of two-thirds line-frequency, some increase in the protection ratio (30 dB) recommended by the CCIR may be necessary, but there is insufficient evidence to permit a firm revised recommendation to be made.

(iv) For precision offsets in the region of two-thirds line-frequency, the CCIR figure of 20 dB should be increased, and a reasonable estimate of the revised value is 24 dB. It should be noted that, because of the relatively low protection ratio permitted in this case, the effect of the interference upon the picture synchronization can cause the impairment to increase very rapidly when the protection ratio is reduced below that corresponding to grade 3·5 impairment.



Figs. 2 to 7

Results of Subjective Tests

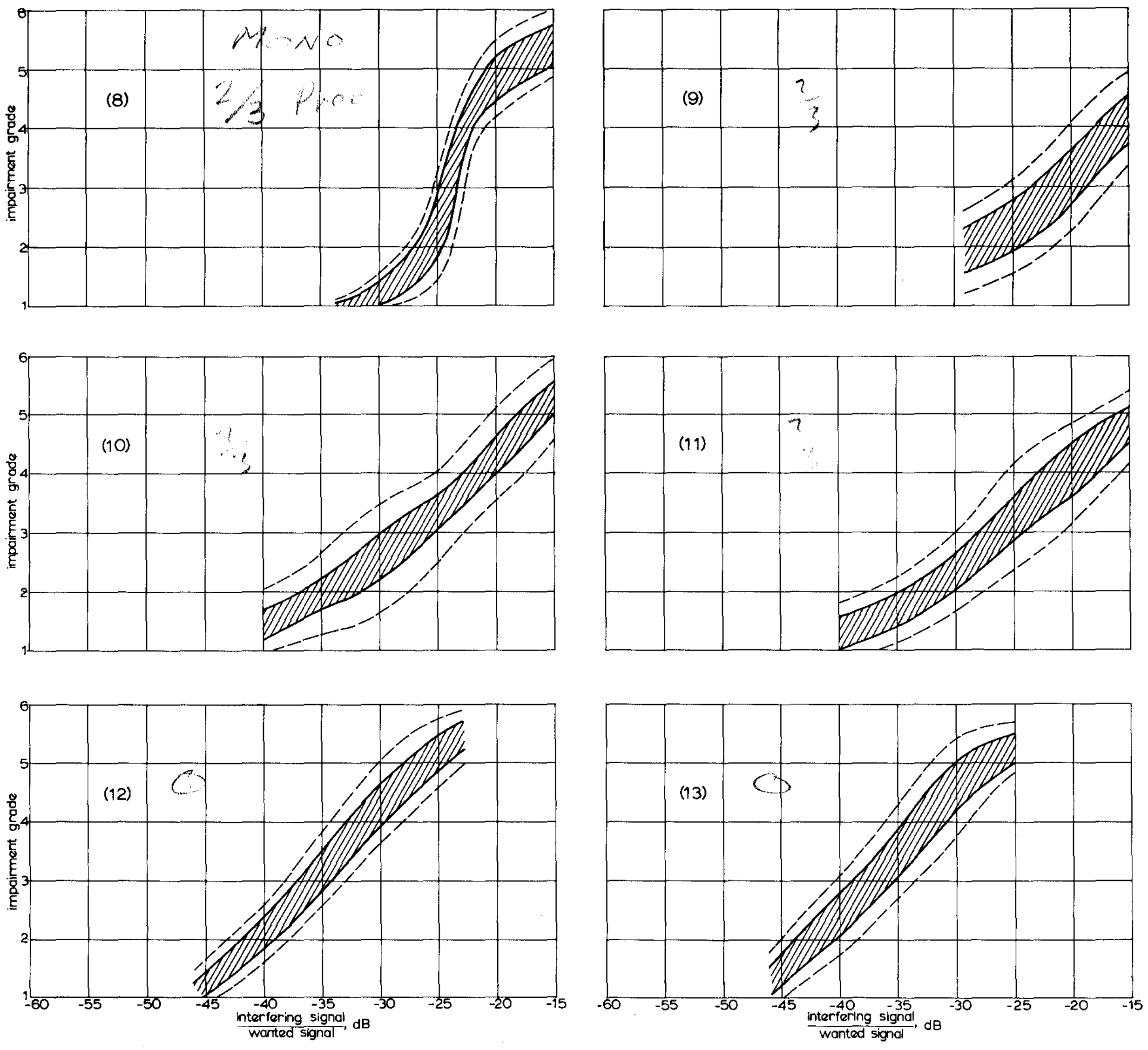
	FIG. 2	*FIG. 3*	*FIG. 4*	*FIG. 5*	*FIG. 6*	*FIG. 7*
No. of observers:	11	11	9	9	9	9
Vision Carrier Offset:	500 Hz	2 Hz	10.425 kHz ± 1 Hz	10.425 kHz ± 1 Hz	10.400 kHz ± 1 Hz	10.400 kHz ± 1 Hz
Interfering Modulation:	Grill pattern	Grill pattern	Grill pattern	Same picture	Colour bars grey scale. Chrominance off	Grill pattern
Interfering Sync. Pulse:	Visible	Visible	Visible	Visible	In phase	Visible

In each case the wanted modulation was 'Girl in Studio', in monochrome.

The display was on a monochrome monitor, externally synchronized by a stable signal

▨ Mean grade, 90% probability

- - - Standard deviation of grade, with small-sample correction



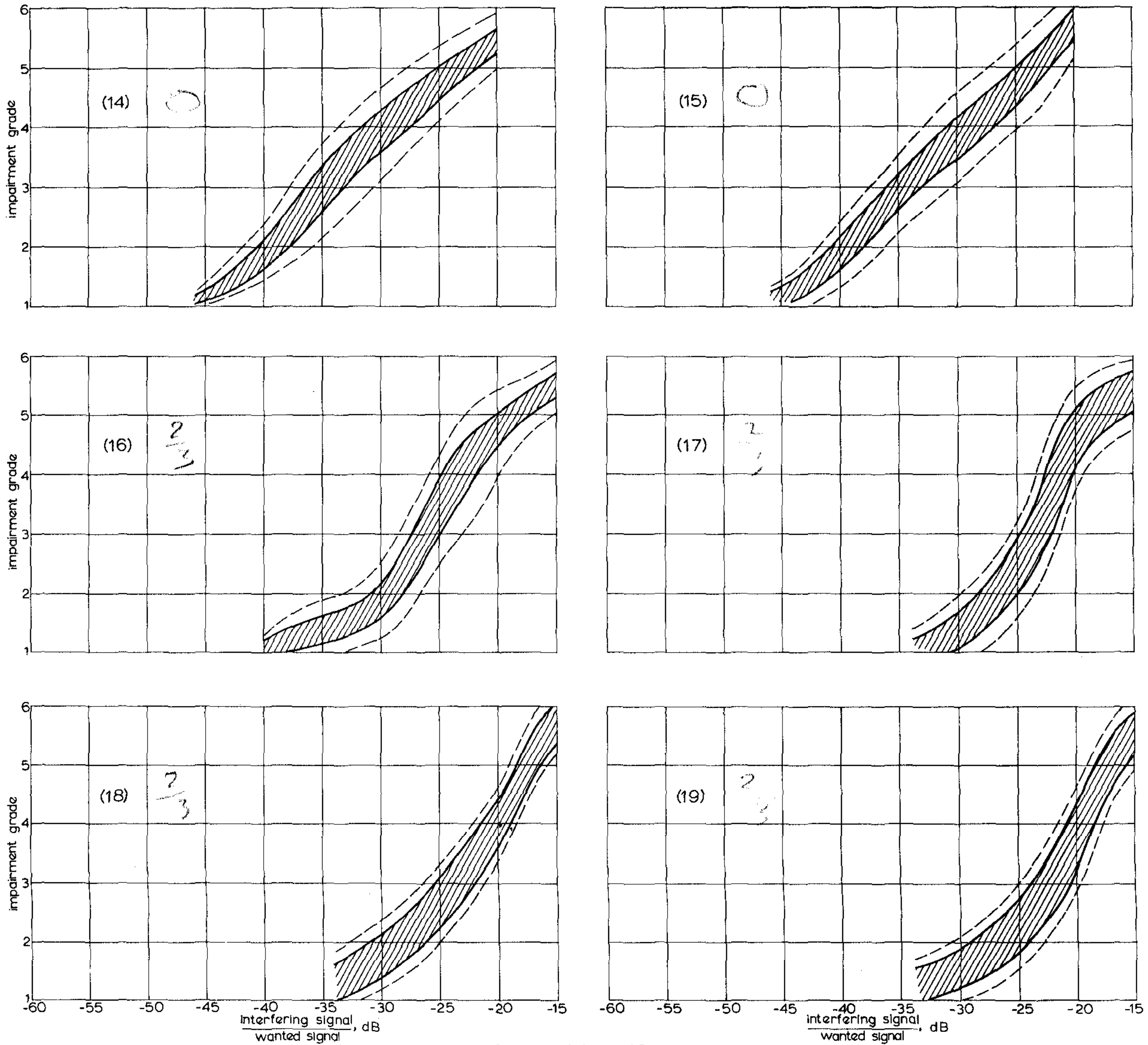
Figs. 8 to 13

Results of Subjective Tests

	FIG. 8	*FIG. 9*	*FIG. 10*	*FIG. 11*	*FIG. 12*	*FIG. 13*
No. of observers:	7	9	16	9	10	10
Vision Carrier Offset:	10·400 kHz ± 1 Hz	10·400 kHz	10·400 kHz ± 1 Hz	10·400 kHz ± 1 Hz	± 2 Hz	± 2 Hz
Colour Sub-Carrier Offset:	0	-	± 1 Hz	± 1 Hz	± 2 Hz	± 2 Hz
Wanted Modulation:	'Girl on Beach'	'Girl in Studio'	'Boy with Toys'	'Boy with Toys'	'Boy with Toys'	'Boy with Toys'
Interfering Modulation:	Same picture	Colour Bars	C.W. Colour Sub-Carrier	C.W. Colour Sub-Carrier	C.W. Colour Sub-Carrier	C.W. Colour Sub-Carrier
Interfering Sync. Pulse:	Nearly in phase	In phase	Visible	Visible	Visible	Visible
Display:	Monochrome	Monochrome	Colour	Monochrome	Colour	Monochrome
Synchronizing:	Internal, from disturbed signal	External, from undisturbed signal	Internal, from disturbed signal	External, from undisturbed signal	Internal, from disturbed signal	External, from undisturbed signal

▨ Mean grade, 90% probability.

— — — Standard deviation of grade, with small-sample correction



Figs. 14 to 19

Results of Subjective Tests

	FIG. 14	*FIG. 15*	*FIG. 16*	*FIG. 17*	*FIG. 18*	*FIG. 19*
No. of observers:	12	12	12	7	7	7
Vision Carrier Offset:	± 2 Hz	± 2 Hz	10.400 kHz ± 1 Hz	10.400 kHz ± 1 Hz	10.400 kHz ± 1 Hz	10.400 kHz ± 1 Hz
Colour Sub-Carrier Offset:	< ± 1 Hz	< ± 1 Hz	0	0	0	0
Wanted Modulation:	'Boy with Toys'	'Boy with Toys'	'Boy with Toys'	'Girl on Beach'	'Girl on Beach'	'Girl on Beach'
Interfering Modulation:	C.W. Colour Sub-Carrier	C.W. Colour Sub-Carrier	Same picture	Same picture	Same picture	Same picture
Interfering Sync. Pulse:	Visible	Visible	In phase	In phase	Visible	Visible
Display:	Monochrome	Colour	Colour	Colour	Colour	Monochrome
Synchronizing:	External, from undisturbed signal	Internal, from disturbed signal	Internal, from disturbed signal	Internal, from disturbed signal	Internal, from disturbed signal	Internal, from disturbed signal

▨ *Mean grade, 90% probability.*

--- *Standard deviation of grade, with small-sample correction*

7. REFERENCES

1. Television co-channel interference at very low offsets. BBC Research Department Report No. T-088, Serial No. 1962/19.

2. Co-channel interference between television signals of the same or different standards. BBC Research Department Report No. T-084, Serial No. 1962/14.

3. Pattern visibility in television co-channel interference. BBC Research Department Report No. T-091, Serial No. 1962/26.

4. The effect on television reception of interference offset by a small frequency. Post Office Engineering Department Research Report No. 20706, August 1961.

5. HOPF, H. 1958. Experiments on the operation of television transmitters with precision-offset carrier frequencies. *Rundfunktechnische Mitteilungen*, 1958, **2**, 6, December, pp. 265-276.

6. C.W. interference with monochrome u.h.f. television reception. BBC Research Department Report No. G-099, Serial No. 1966/7.

7. BEHREND, W.L. 1959. Reduction of co-channel interference by precision frequency control of television picture carriers. *Part II, RCA Review*, 1959, **XX**, 2, June, pp. 349-364.

8. CHAPIN, E.W., MIDDLEKAMP, L.C. *and* ROBERTS, W.K. 1958. I.R.E. Transactions on broadcast transmission systems, 1958, **PGBTS-10**, June, pp. 3-24.

9. Comparison of the protection required between PAL transmissions when the sub-carriers differ by 2 c/s and 10 c/s. EBU Document Com.T(E) 235.

10. Technical Data used by the European VHF/UHF Broadcasting Conference, Stockholm, 1961. See CCIR Documents of the XIth Plenary Assembly, Vol. V, Recommendation 418-1, and Report 306, Oslo, 1966.

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